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(54) Chip antenna

(57) A chip antenna (10) exhibiting directivity to a plurality of planes of polarization and a wide bandwidth, which comprises a substrate (11) either of a dielectric material or a magnetic material, at least one conductor (14) meanderingly formed on the surface of the substrate (11) and/or inside the substrate and having at least one change of direction, e.g., a corner, and at least one feeding terminal (15) provided on the surface of the substrate (11) for applying a voltage to the conductor.

The chip antenna further comprises at least one fixing terminal (16) to fix the substrate (11) to a surface of a mounting board.

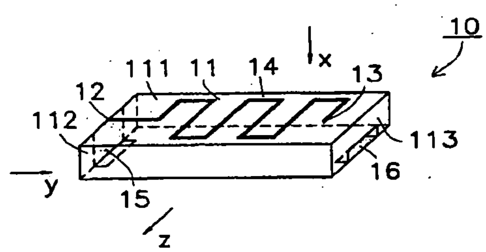

FIG. 1

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Descripti n

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to chip antennas. In particular, the present invention relates to a chip antenna used for mobile communication and local area networks (LAN).

2. Description of the Related Art

A prior art chip antenna is disclosed, for example, as "a microstrip antenna" at page 1,353 of "Denshi Joho Tsushin Handbook", Volume 1 edited by Denshi Joho Tsushin Gakkai (The Institute of Electronics, Information and Communication Engineers) (Published on March 30, 1988, Publisher: Ohm K.K.).

Fig. 10 is an isometric view illustrating a prior art microstrip antenna described in the document set forth above. The microstrip antenna 1 has a dielectric substrate 2 which is provided with a meandering strip conductor 3 having a plurality of corners on the front surface, and a grounding electrode 4 on the back surface. The strip conductor 3, as well as the dielectric substrate 2 and the grounding electrode 4, comprises a microstrip line.

However, in the prior microstrip antenna 1 set forth above, polarization of radio waves is singular, and a plurality of radio waves having various planes cannot be radiated, in other words, the antenna exhibits only the upward directivity of the dielectric substrate 2.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a chip antenna which exhibits directivity to a plurality of planes of polarization and a wide frequency bandwidth.

In accordance with the present invention, a chip antenna comprises a substrate comprising either of a dielectric material or a magnetic material, at least one conductor meanderingly formed on the surface of the substrate and/or inside the substrate and having at least one corner, and at least one feeding terminal provided on the surface of the substrate for applying a voltage to the conductor.

Further, the chip antenna comprises at least one fixing terminal to fix the substrate to a surface of a mounting board.

Because the chip antenna in accordance with the present invention comprises a substrate formed of either of a dielectric material or a magnetic material, the propagation speed is lowered and the wavelength is shortened. Thus, the effective line length becomes $\varepsilon^{1/2}$ times the dielectric constant ε of the dielectric material or the magnetic material.

Further, when the fixing terminal is provided, the chip antenna can be stably fixed to a surface mounting board.

Other features and advantages of the present invention will become apparent from the following description of the invention which refers to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an isometric view illustrating a first embodiment of a chip antenna in accordance with the present invention;

Fig. 2 is an isometric view illustrating a second embodiment of a chip antenna in accordance with the present invention;

Fig. 3 is a decomposed isometric view of the chip antenna in Fig. 2;

Fig. 4 is an isometric view illustrating a third embodiment of a chip antenna in accordance with the present invention;

Fig. 5 is a decomposed isometric view of the chip antenna in Fig. 4;

Fig. 6 is a graph illustrating reflection loss characteristics of the chip antenna in Fig. 1;

Fig. 7 is a graph illustrating the sensitivity of the chip antenna in Fig. 1 to the cross polarization in the x- axis direction;

Fig. 8 is a graph illustrating the sensitivity of the chip antenna in Fig. 1 to the cross polarization in the y- axis direc-

tion;

Fig. 9 shows other embodiments of the meandering conductor of the chip antenna in accordance with the present invention, (a) being wavy and (b) being sawtooth; and

Fig. 10 is a cross-sectional view of a prior art chip antenna.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Embodiments in accordance with the present invention will now be explained. In the embodiments, the same number in the figures means the same section or part.

Fig. 1 is an isometric view illustrating a first embodiment of a chip antenna in accordance with the present invention. The chip antenna 10 is formed as follows: on one main surface 111 of a rectangular parallelepiped substrate 11, which is formed by layering a plurality of dielectric materials containing titanium oxide and barium oxide as a main component, a conductor 14 comprising copper or a copper alloy and having a feeding end 12 and a free end 13 is fixed as a meandering line having ten corners by printing, evaporation, adhesion, or plating, etc. The meandering conductor 14 is provided from one side to the opposing side of the rectangular parallelepiped substrate 11.

A feeding terminal 15 connecting to the feeding end 12 of the conductor 14 is provided at one side 112 of the ba substrate 11, and a fixing terminal 16 to fix the chip antenna 10 to a mounting board (not shown in the figure) having an external circuit is provided at the other side 113.

Reflection loss and sensitivity of the chip antenna obtained by such a way were measured. Fig. 6 is a graph illustrating the reflection loss, Fig. 7 is a graph illustrating the sensitivity to a main polarization in the x-axis direction, and Fig. 8 is a graph illustrating the sensitivity to a main polarized wave in the y-axis direction.

The results of the reflection loss in Fig. 6 demonstrate that the bandwidth H of the chip antenna 10 is 140 MHz and is approximately seven times the band-width, 20 MHz, of the prior art microstrip antenna 1. Further, the results of sensitivities in Figs. 7 and 8 demonstrate that the chip antenna 10 responds to main polarized waves in the x- and y-axes and substantially works as an isotropic antenna.

In the first embodiment as set forth above, the chip antenna 10 substantially works as an isotropic antenna to main polarized waves in the x- and y-axes, and thus exhibits directivity to a plurality of planes of polarization.

Further, since the conductor 14 is provided as a meandering line having ten corners on one main surface 111 of the substrate 11, the line can be lengthened. Thus, the bandwidth can be expanded without a decrease in gain.

Moreover, due to the substrate 11 comprising a dielectric material, the propagation speed is lowered to shorten the wavelength, and thus the effective length is increased, for example, the effective line length is $\varepsilon^{1/2}$ times that when the dielectric constant of the substrate 11 is ε. Because the region distributing electric current increases thereby, the radiation wave pattern increases, the gain of the antenna is improved, and the bandwidth is expanded.

On the other hand, when the characteristics of the chip antenna 10 are matched to those of a prior art chip antenna, the line length becomes $1/\varepsilon^{1/2}$, enabling the miniaturization of the chip antenna 10.

Figs. 2 and 3 are an isometric view and a decomposed isometric view, respectively, illustrating a second embodiment of the chip antenna in accordance with the present invention. The chip antenna 20 is formed as follows: in a rectangular parallelepiped substrate 21, which is formed by layering a plurality of dielectric materials containing titanium oxide and barium oxide as a main component, a conductor 24 comprising copper or a copper alloy and having a feeding end 22 and a free end 23 is fixed as a meandering line having ten corners. The meandering conductor 24 is provided from one side to the opposing side of the rectangular parallelepiped substrate 21, similar to the first embodiment.

A feeding terminal 15 connecting to the feeding end 22 of the conductor 24 is provided at one side 211 of the ba substrate 21, and a fixing terminal 16 to fix the chip antenna 20 to a mounting board (not shown in the figure) having an external circuit is provided at the other side 212, similar to the first embodiment.

The chip antenna 20 is formed by providing a meandering conductor 24 on the surface of the sheet layer 21b comprising the substrate 21 by printing, evaporation, adhering or plating, etc. and then by layering the sheet layers 21a through 21c.

Because the conductor 24 is sealed in the substrate 21 in the second embodiment, the wavelength can be further shortened compared with the first embodiment, and the effective line length of the chip antenna 20 is further lengthened. Therefore, the gain can be further improved, and the bandwidth can be further expanded.

Further, a compact and inexpensive chip antenna 20 can be produced by layering.

In the first and second embodiments, although a material containing titanium oxide and barium oxide as a main component is used for the substrate 11, any other dielectric materials and magnetic materials may be used.

Table 1 shows relative bandwidths at the resonance point of the chip antenna using a dielectric material or a magnetic material for the substrate 11, in which material Nos. 1 to 9 represent dielectric materials, and material Nos. 10 to 12 represent magnetic materials. The relative bandwidth is determined by the equation: the relative bandwidth [%] = (bandwidth [GHz]/center frequency [GHz]) X 100 . The chip antenna is prepared for 0.24 GHz and 0.82 GHz by

adjusting the number of the corners and the length of the conductor 14.

Table 1

Sample No.	Composition	Relative bandwidth	
		0.24 GHz	0.82 GHz
1	Bi-Pb-Ba-Nd-Ti-O	1.1	1.0
2	Pb-Ba-Nd-Ti-O	1.7	1.5
3	Ba-Nd-Ti-O	2.4	2.3
4	Nd-Ti-O	2.9	2.7
5	Mg-Ca-Ti-O	3.1	3.0
6	Mg-Si-O	3.5	3.3
7	Ba-Al-Si-O	3.8	3.4
8	(Ba-Al-Si-O)+ Teflon Resin	4.1	3.7
9	Teflon Resin	4.5	4.3
10	Ni/Co/Fe/O=0.47/0.06/0.94/4.00	2.5	2.4
11	Ni/Co/Fe/O=0.45/0.08/0.94/4.00	3.0	2.7
12	(Ni/Co/Fe/O=0.45/0.08/0.94/4.00) + Teflon Resin	3.2	3.0

These results demonstrate that antenna characteristics or relative bandwidths of each sample are very similar to each other, even if either of a dielectric material or a magnetic material is used for the substrate 11 of the chip antenna 10.

As a third embodiment, a conductor 35 may be formed, as shown in Figs. 4 and 5, by connecting conductive patterns 33a through 33c, provided on the surface of the sheet layers 32a through 32c comprising the substrate 31 of the chip antenna 30, with via holes 34.

In the first and second embodiments, although a rectangular meandering conductor has been explained, a wavy meandering conductor and a sawtooth meandering conductor may be used as shown in Figs. 9(a) and 9(b). Other shapes can also be used.

Further, although a meandering conductor is formed in the substrate in the first embodiment or on the surface of the substrate in the second embodiment, the meandering conductor may be provided on an inner surface of a cavity provided inside the substrate. The resonance frequency can be adjusted by the size of the cavity, in this case.

Although the number of the corners of the meandering conductor is ten in the first and second embodiments, the number of one or more can be selected according to the line length.

The direction of the meandering conductor may be adequately determined, although the meandering conductor is formed from one side to the opposing side in the first to third embodiments.

A plurality of conductors can be formed, in addition to the first and second embodiment in which the conductor is single.

The conductor may be formed both on the surface of the substrate and inside the substrate, in addition to the first and second embodiments in which the conductor is formed on the surface of the substrate or inside the substrate.

The substrate can be formed of a single material, although it is preferably formed by layering a plurality of sheet layers in the first embodiment.

The meandering conductor can be formed inside the substrate by providing the meandering conductor on the surface of the substrate, and then by sealing or blocking with other substrate(s) comprising a dielectric or magnetic material, although the meandering conductor is provided inside the substrate by layering a plurality of sheet layers in the second embodiment.

Any low resistive materials, such as, e.g., gold, silver, platinum, and palladium (or alloys of these) can be used as the conductor, although copper or a copper alloy is used in the first and second embodiments.

The substrate may be of other shapes, e.g., spherical, cubic, cylindrical, conical, or pyramid, in addition to rectangular parallelepiped as in the first and second embodiments.

The positions of feeding and fixing terminals are not essential for the practice of the present invention.

The chip antenna in accordance with the present invention substantially works as an isotropic antenna to main

polarization in the x- and y-directions, and thus has directivity to a plurality of planes of polarization.

Further, because the conductor having at least one corner is meanderingly provided on the surface of the substrate and/or inside the substrate, the line length is lengthened. Thus, the bandwidth can be expanded without gain loss.

Moreover, because the chip antenna comprises a substrate formed of either of a dielectric material or a magnetic material, the propagation speed is lowered and the wavelength is shortened. Thus, the effective line length becomes $\varepsilon^{1/2}$ times the dielectric constant ε of the dielectric material or the magnetic material. Thereby, the current distribution region increases, the emitted radio wave increases, the gain of the antenna is further improved, and the bandwidth is further expanded.

On the other hand, when a chip antenna in accordance with the present invention, which has characteristics similar to a prior art chip antenna, is produced, it can be miniaturized because the line length is shortened to $1/\varepsilon^{1/2}$.

Additionally, when the fixing terminal is provided, the chip antenna can be stably fixed to a surface mounting board.

Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. Therefore, the present invention should be limited not by the specific disclosure herein, but only by the appended claims.

Claims

1. A chip antenna comprising a substrate (11; 21; 31) of one of a dielectric material and a magnetic material, at least one conductor (14; 24; 35) meanderingly formed on at least one of a surface of said substrate and inside said substrate and having at least one change of direction, and at least one feeding terminal (15) provided on the surface of said substrate (11; 21; 31) for applying a voltage to said conductor (14; 24; 35).

2. A chip antenna according to claim 1, wherein said chip antenna further comprises at least one fixing terminal (16) to fix said substrate (11; 21; 31) to a surface of a mounting board.

3. A chip antenna according to claim 1 or 2, wherein the change of direction comprises a corner.

4. A chip antenna according to any of claims 1 to 3, wherein the conductor (14; 24; 35) is formed in the shape of a square wave.

5. A chip antenna according to any of claims 1 to 3, wherein the conductor (14; 24; 35) is one of wavy and sinusoidal in shape.

6. A chip antenna according to any of claims 1 to 3, wherein the conductor (14; 24; 35) is sawtooth in shape.

7. A chip antenna according to any of claims 1 to 6, wherein the conductor (14) is disposed on an outer surface of the substrate (11).

8. A chip antenna according to any of claims 1 to 7, wherein the substrate (21) comprises a plurality of layers (21a; 21b; 21c), the conductor (24) being disposed on a surface of an inner one (21b) of said layers such that when the layers are sandwiched together the conductor (24) is disposed inside the substrate (21).

9. A chip antenna according to any of claims 1 to 7, wherein the substrate (31) comprises a plurality of layers (32a; 32b; 32c; 32d), portions (33a; 33b; 33c) of the conductor (35) being disposed on surfaces of respective ones of the layers, via holes (34) being provided in ones of said layers such that when the layers are sandwiched together, the via holes (34) interconnect the respective portions (33a; 33b; 33c) to form the conductor (35).

10. A chip antenna according to any of claims 1 to 9, wherein the antenna has directivity in a plurality of planes of polarization and is isotropic in at least two axes.

11. A chip antenna according to any of claims 1 to 10, wherein the conductor (14; 24; 35) comprises one of gold, silver, platinum, palladium, copper and alloys of same.

12. A chip antenna according to any of claims 1 ot 11, wherein the substrate (11; 21; 31) comprises one of a rectangular parallelepiped, cube, cylinder, cone or pyramid.

13. A chip antenna according to any of claims 1 to 12, wherein the substrate (11; 21; 31) contains an inner cavity, the conductor being disposed on a surface of said inner cavity.

14. A chip antenna according to claim 1 or 2, wherein the change of direction comprises a curve.

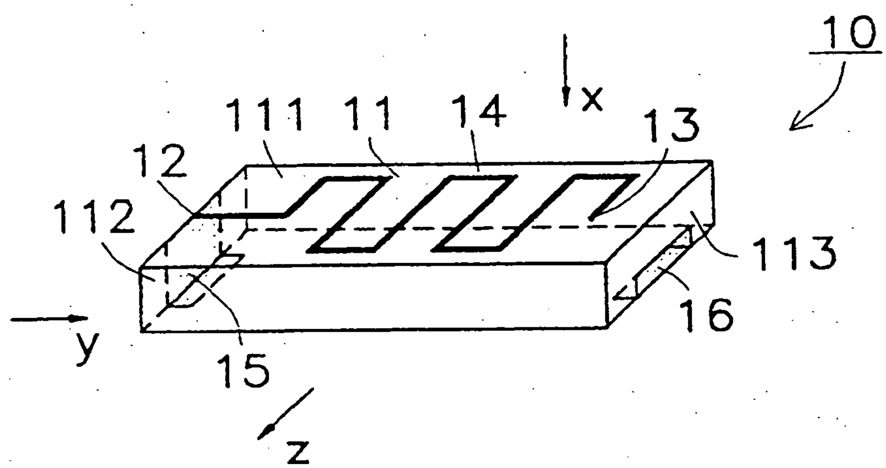

FIG. 1

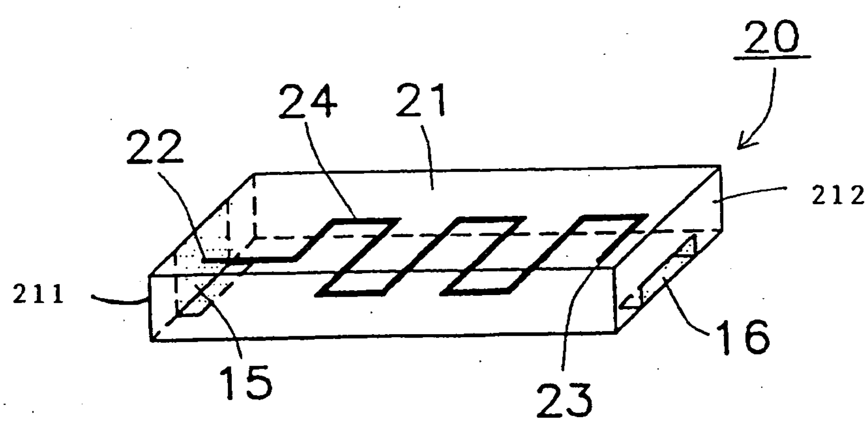

FIG. 2

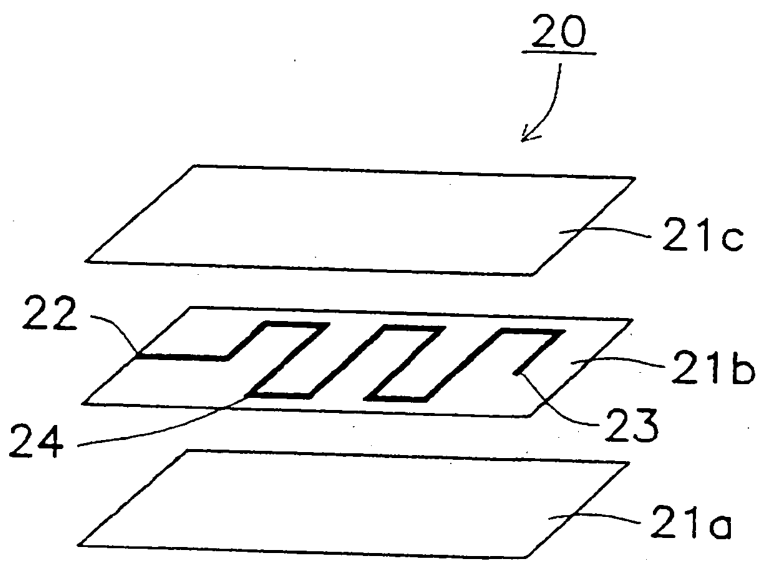

FIG. 3

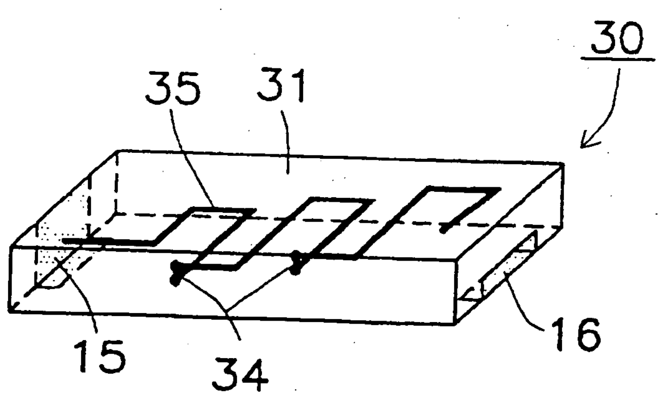

FIG. 4

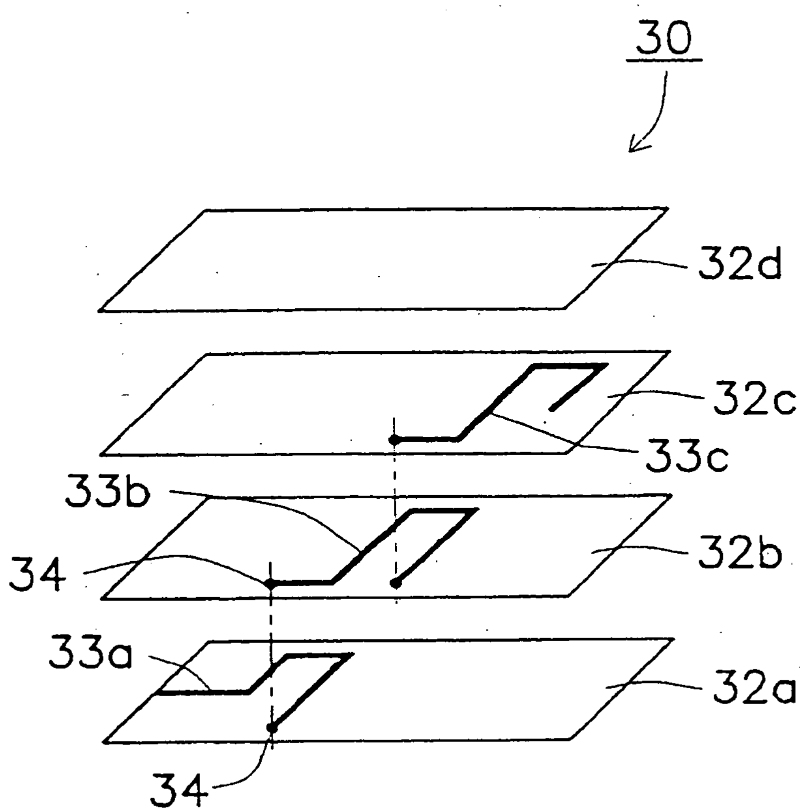
30
32d
32c
33c
33b
32b
34
33a
32a
34

FIG. 5

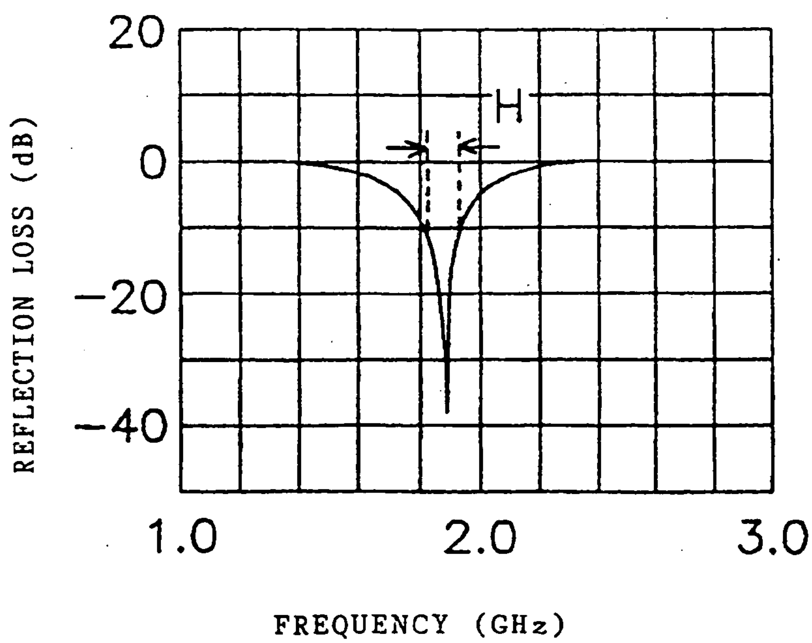
20
0
−20
−40
H
REFLECTION LOSS (dB)
1.0
2.0
3.0
FREQUENCY (GHz)

FIG. 6

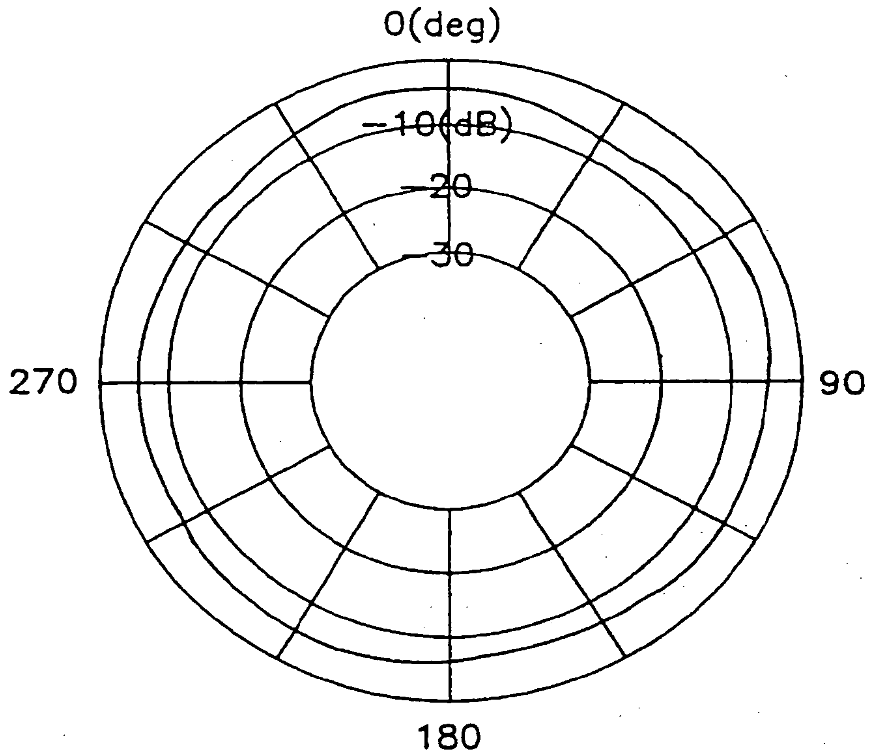

FIG. 7

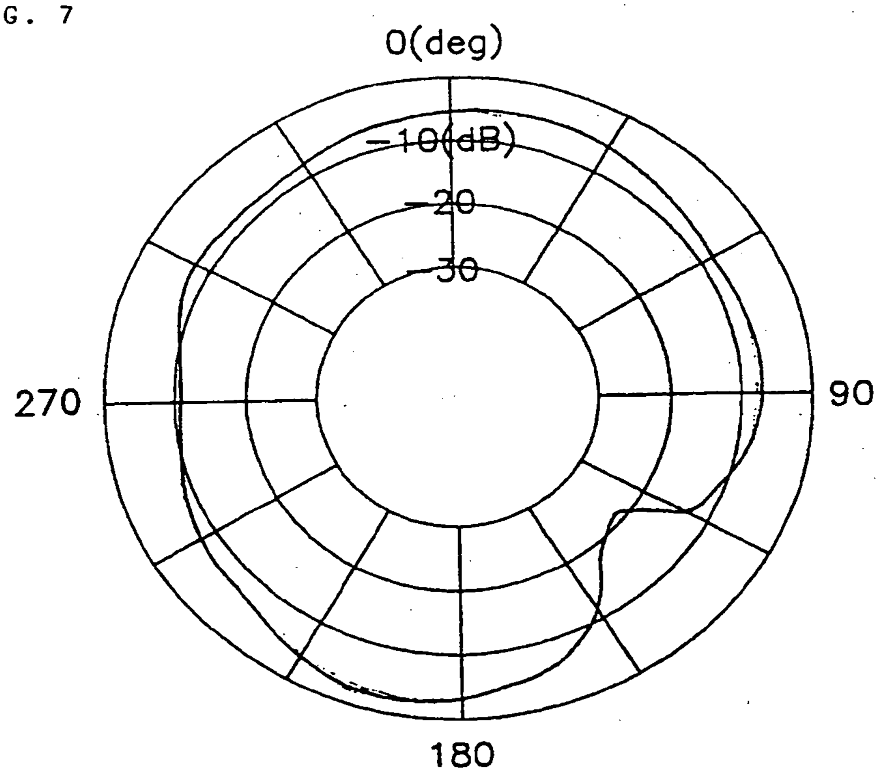

FIG. 8

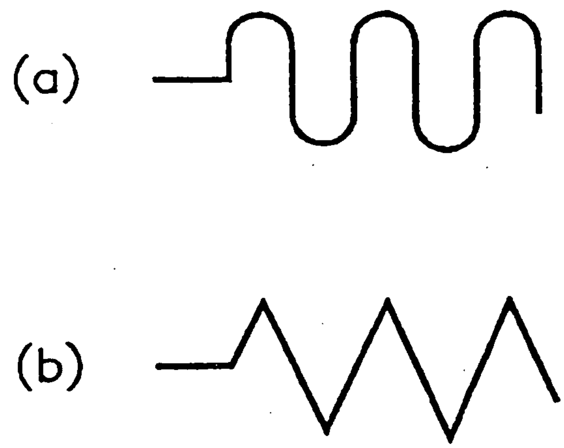

FIG. 9

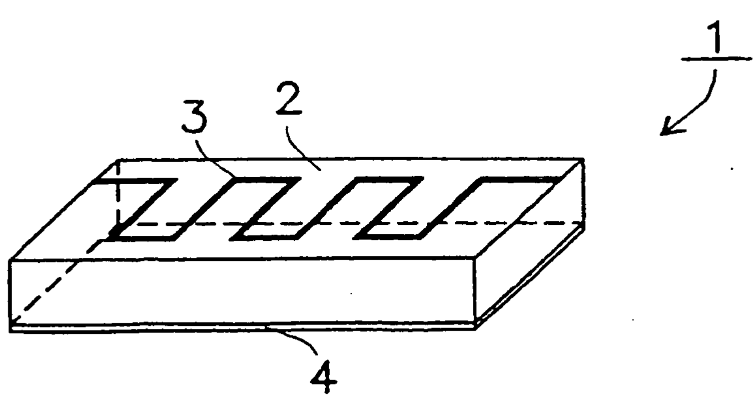

FIG. 10 PRIOR ART

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EUROPEAN SEARCH REPORT

Application Number
EP 96 11 3098

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X,P	EP-A-0 706 231 (MITSUBISHI ELECTRIC CORP) 10 April 1996 * column 4, line 50 - column 5, line 38; figures 2A,2B * ---	1-3, 7-10,12	H01Q13/20
X	US-A-4 475 107 (MAKIMOTO TOSHIO ET AL) 2 October 1984 * column 3, line 19 - column 3, line 57; figures 2,3 * ---	1-4,7, 10,12	
X	US-A-4 398 199 (MAKIMOTO TOSHIO ET AL) 9 August 1983 * column 3, line 13 - column 3, line 46 * * column 4, line 8 - column 4, line 26 * * column 6, line 49 - column 6, line 59; figures 1,2,10,11 * ---	1-5,7, 10,12,14	
X	US-A-3 717 878 (MOSKO J) 20 February 1973 * column 2, line 43 - column 3, line 5; figures 1,3,4 * ---	1-4,7,9, 10,12,13	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
X	WO-A-93 00721 (SIEMENS AG) 7 January 1993 * page 12, line 25 - page 12, line 35; figures 1-5 * ---	1-4,6,7, 10-12	H01Q
X	DE-A-31 29 045 (PLATH NAUT ELEKTRON TECH) 28 October 1982 * claim 5; figures 1,2 * ---	1-4,6,7, 10,12	
X	PATENT ABSTRACTS OF JAPAN vol. 008, no. 099 (E-243), 10 May 1984 & JP-A-59 017705 (TDK KK), 30 January 1984, * abstract * --- -/--	1-3, 8-10,12	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	25 November 1996	McLean, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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L : document cited for other reasons

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EUROPEAN SEARCH REPORT

Application Number
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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	PATENT ABSTRACTS OF JAPAN vol. 018, no. 311 (E-1561), 14 June 1994 & JP-A-06 069057 (TAIYO YUDEN CO LTD), 11 March 1994, * abstract *	1-3, 8-10,12	
X	PATENT ABSTRACTS OF JAPAN vol. 006, no. 160 (E-126), 21 August 1982 & JP-A-57 080804 (NEC CORP;OTHERS: 01), 20 May 1982, * abstract *	1-3,5,7, 10,12-14	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)

The present search report has been drawn up for all claims

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L : document cited for other reasons

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